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Effects of basaltic mineral fines on composting

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Abstract

A by-product of the construction aggregate industry is fines or dust that contain trace elements such as zinc and copper and significant amounts of iron, aluminum, silica and potassium. Beneficial uses for these materials have been proposed such as replenishing depleted soils and amendment in mixtures of organic byproducts prior to composting. To evaluate the beneficial uses in composting, outdoor bin studies were conducted using a beef cattle manure, straw and wood chip mixture amended with and without basaltic mineral fines. Temperature differences in composting mixtures of equal volumes, equal moisture and relatively equal material content are considered an indication of differing biological activities [Haug, Compost Engineering Principles and Practice. Ann Arbor Science, Ann Arbor, MI. (1980)] . Temperatures were lower in the mineral fine-treated manure mixture initially. After turning the piles at six weeks, temperatures tended to be higher in the mineral fine amended mixture. Overall, temperatures were not significantly different suggesting that mineral fines amendment does not significantly increase temperature and activity in composting mixtures.
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Keywords: Composting; Rock dust; Mineral fines; Microorganisms; Biological activity

1. Introduction

Approximately two billion tons of construction aggregates are crushed and screened annually in the USA. More than 5% ends up as mineral fines or, by another name, rock dust. These by-products contain ingredients such as silica, iron, aluminum, calcium, magnesium, potassium and trace elements zinc, copper, chromium, cobalt and manganese. Studies reported in both popular and scientific press suggest that the return of this by-product to soil or its addition to horticultural mixes will provide benefits equal or beyond those of commercial fertilizers (O'Brien et al., 1999). Since fertilizers do not contain the myriad of ingredients that dusts have, these fines may or should benefit soils depleted in trace nutrients.

Quality of minerals in soil has some bearing on its organic matter content. Soil containing highly stable soil organic matter has a metastable non-crystalline mineral content (Torn et al., 1997). These types of minerals include allophane, imogolite and ferrihydrite and are characterized as having a high degree of hydration, extensive surface area and a variable charge. Szmidt et al. (1997) reported that one benefit of mineral fines addition to composting mixtures is reduction of ammonia loss. The authors attributed this characteristic to possible surface area increases with addition of mineral fines. Microbial activity may be a key to releasing to soils the beneficial properties associated with the addition of mineral fines. Banfield et al. (1999) showed that microorganisms cause disaggregation, dissolution and secondary mineral formation. These actions would impact soil fertility.

Addition of mineral fines to composts may enhance the composting process by stimulating biological activity and/or improve the quality of the compost product (O'Brien et al., 1999). Investigations comparing composting of beef cattle manure to composting beef cattle manure mixed with basaltic mineral fines were conducted. Temperature difference in composting mixtures of equal volumes, equal moisture, and relatively equal material content was considered an indication of differing biological activities (Haug, 1980).

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2. Materials and methods

Beef cattle manure (Table 1) was mixed with hay and wood chips in a volumetric ratio of 2:7:1. Total volume of treatment mixture was 16 m^3 . Basaltic mineral fines from Connecticut, USA (Table 2) was added to the manure–hay–wood chip mixture in four portions with mixing in between each addition at a final rate of 3.3 kg /m^3. This rate is within the range of 1.2 to 12 kg m^3 recommended by Remineralize the Earth, Inc. for amendment to mixtures for composting. This organization promotes the use of minerals as fertilizers and compost amendments. Handling of the mineral fines-amended mixture which was done using a front-end loader was duplicated for unamended mixture. The final mixtures were divided in half and placed in two duplicate concrete outdoor bins. The outdoor bins, located in a covered pole building at the Beltsville Agricultural Research Center Compost Research facility, were 3 × 3 m with 1.25 m walls on three sides. Each outdoor bin contained two 5 cm plastic manifolds containing five thermocouples each. The manifolds were located at 45 and 90 cm from the bin floor. Passive aeration was used. After six weeks the manifolds were removed and the materials in all bins were mixed using a front end loader and returned to the bins with manifolds placed in the same location. Total nitrogen of composts was determined by block digestion and flow injection analysis (Lachat Instruments, Loveland, CO, Method 13-107-06-2-D).

Table 1
Chemical analysis of basaltic mineral fines from Holyoke Basin, Connecticut

Component	Basaltic mineral fines
SiO_2	51.3[a]
Fe_2O_3	10.6
Al_2O_3	13.3
CaO	8.4
MgO	4.9
SO_3	<0.1
Cu	56–181[b]
Zn	69–120[b]
Ni	9–40[b]
Cr	<1–20[b]
Co	49-82[b]
Diameter <400 :M	86.5

[a] Percent, dry weight.
[b] Range total mg kg^{-1} (personal communication, Anthony Philpotts, University of Connecticut).

Table 2
Chemical characteristics of beef cattle manure

Constituents	Concentration (mg/kg dry wt.)
Nitrogen	21 000
Phosphorus	4600
Manganese	188
Copper	34
Boron	55
Zinc	118

3. Results

Temperatures typical of composting manures were observed (Fig. 1). Temperatures were about 5 °C lower for the mineral fines-amended manure during the first week. After mixing at six weeks, temperatures were consistently but not significantly higher in the mineral fine-amended mixture. Statistical analyses (standard *T* test) of temperatures over the entire study however indicated that temperatures of treatments were not significantly different. A preliminary study using dairy manure and conducted in a similar manner, but containing too few thermocouples for adequate statistical analyses, had similar results. Unamended mixtures had higher temperatures for the first 30 days, but after the materials were mixed at 40 days, the mineral fines-amended mixture had higher temperatures for the remainder of the process.

4. Discussion

Statistics showed that mineral fines-amended manure does not generate higher temperatures (and thus activity) than unamended beef cattle manure during composting. Lower temperatures initially followed by higher temperatures after mixing were consistent with a preliminary study using dairy manure. Higher temperatures after 4 weeks of composting may be due to microbial or chemical transformation and mixing resulted in distribution of products that led to greater activity and increased temperatures. Mineral dissolution studies with bacteria and fungi show increasing dissolution rates of feldspar, biotite, quartz, and other minerals with increased microbial populations (Banfield et al., 1999). Acid production is the most basic mechanism by which microbes affect weathering of minerals. One mechanism by which acid production causes mineral weathering is that at acid pHs Fe and Al solubility increases leading to formation of secondary minerals such as aluminosilicates, kaolinite and halloysite (Banfield et al., 1999). In addition microbes can catalyze mineral weathering by production of organic ligands. Iron is one of the key metals needed for biological activity and microorganisms obtain Fe by producing siderophores which chelate the iron and make it available for microbial growth (Buyer and Sikora, 1990). Microbes also produce polymers that affect mineral weathering. Slimes that coat surfaces are 99% water which promotes diffusion of ions away from the surface (Banfield et al., 1999).

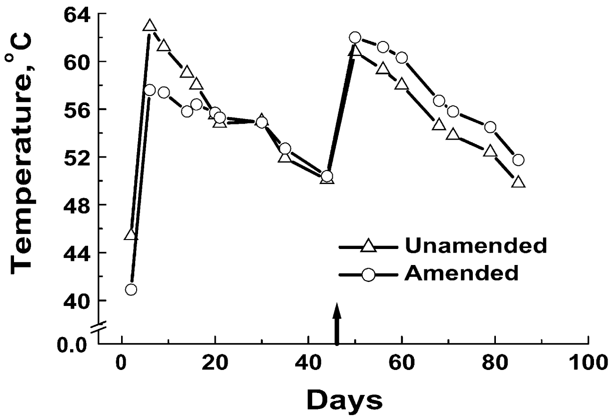

Fig. 1. Temperatures (mean) during composting of beef cattle mixtures amended with and without basaltic rock mineral amendment. Arrow indicates when piles were mixed and replaced.

Rhizosphere microorganisms release organic acids that help dissolve minerals (Grinsted et al., 1982). Banfield et al (1999) point out that microbes can catalyze mineral weathering by production of organic lignads. Ligands complex with ions on the mineral surface and can weaken metal–oxygen bonds. Indirectly the ligands affect reactions by forming complexes with ions in solution, decreasing solution saturation states. Many microorganisms produce polysaccharides that facilitate weathering by complexing with ions in solution and lowering their solution saturation state. With less minerals in solution, more dissolution from mineral surfaces will take place to substitute for those minerals chelated by microbial products. Minerals also tend to dissolve faster at higher temperatures (Harley and Gilkes, 2000) and in the presence of carbonic acids from microbial respiration (Barker et al., 1997). These reports would suggest that as composting proceeds, biological activity would dissolve minerals and beneficial soluble minerals may result. Mixing the compost would distribute these solubilized minerals throughout the mass.

Recent studies suggest stimulation of compost activity with mineral fine addition. Garcia-Gomez (2002) amended a poultry manure–sawdust mixture with rock dust from glacial silt and quartz dolerite at a rate of 20 kg m^3 and recorded increased temperatures, protein content and oxygen demand over the unamended control. Sikora et al. (unpublished data) found that addition of basaltic mineral fines to yard debris followed by composting in an insulated container resulted in higher temperatures than in unamended yard debris composting. So what would cause the lower temperatures at the start of the composting? Increased surface area of the mixture containing fines may have adsorbed microbial nutrients such as ammonium. Szmidt et al. (1997) recorded decreased ammonia losses when composting poultry manure with mineral fines. Laboratory compost studies showed that mineral fines addition to cattle manure reduced ammonia volatilization (Sikora et al., unpublished data). The possibility of toxic metal addition as a cause for lower temperatures is unlikely. Table 2 presents metal data from a survey of the Holyoke basin and the concentrations are lower than those allowed in the EPA Part 503 rule for application of biosolids to land. Further, if high metal content was the cause of the lower temperatures, the effect should not disappear in 3 weeks or be reversed by mixing. O'Brien et al. (1999) extracted media containing 60 or 120 g l^{-1} basaltic or glacial moraine fines and food byproduct compost used for tomato production. Using acidified sodium acetate they found no differences in Zn, Cu, Mg, and K between media containing fines and media without fines. Harley and Gilkes (2000) summarized the literature on plant nutrient in igneous and metamorphic minerals. With few exceptions that were not basalt, only trace amounts of Cu, Zn, Mo, and Co were recorded. Therefore mineral fine metal content is not the probable cause of initial lower temperatures.

A comparison of total N contents of post compost samples run simultaneously and analyzed with the same standards indicated no difference between mineral fines-amended composts and unamended composts (data not presented). Therefore, NH_3 losses from the treatments were equal which is different from that report by Szmidt et al. (1997).

Beneficial use of byproducts normally require more than one option for successful implementation. If basaltic rock dust has a beneficial effect on composting and the final compost, the cost of materials handling and shipping from storage areas would be balanced against the benefit. The recommended amendment rate ranges from 1.2 to 26 kg m^3. For a large composting facility handling 1000 m^3 per day and using the highest amendment rate, nearly 3 Mt of fines would be used daily. This beneficial use would be a small volume market for the mineral fines industry but may have importance and thus added value in animal-raising areas where manure disposal is often problematic and compost production and high-value horticultural markets may be outlets for both byproducts.

Further studies are necessary to explore more carefully the mineral-microbial interaction which is known to occur over lengthy contact times (months and years) in soils and whether during composting, alteration of mineral surface or solubility of minerals occurs to a significant extent. Until differences in activity in composting are recorded in the field showing significant effects, the beneficial effects on mineral fines in composting is still conjecture.

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